Fast Detection of a Punctured

The noninvasive pneumothorax detector connects to a standard personal digital assistant. A graphical user interface guides diagnosis.

PNEUMOTHORAX is a respiratory condition in which air is trapped in the pleural space—the space between the wall of the chest cavity and the lung. The condition is usually attributed to a fractured rib puncturing the lung. If not treated quickly, it can become life-threatening in minutes. Prompt diagnosis is difficult, especially in remote or combat environments where x-ray and computed tomography (CT) systems are not available. The noninvasive pneumothorax detector, developed by Livermore scientists in collaboration with ElectroSonics Medical, Inc., can diagnose this serious condition in seconds.

The project team, led by Livermore engineer John Chang, won a 2007 R&D Award for the handheld detector. Detroit Receiving Hospital and Sinai-Grace Hospital, both of the Detroit Medical Center, collaborated on the project. The device uses the ultrawideband (UWB) technology pioneered by Lawrence Livermore, and the development effort received early support from Livermore's Laboratory Directed Research and Development Program.

The battery-operated detector is ideal for trauma situations where low weight, low power consumption, and insensitivity to acoustic and electromagnetic noise are critical. "The concept came about in 1999 from my experience and interest as an emergency medical technician for search and rescue operations," says Chang.

Faster, Lighter, Cheaper

The traditional process for diagnosing pneumothorax is time-consuming. Emergency response personnel first examine the patient, looking for signs of respiratory distress, feeling for broken ribs, and listening for sounds of diminished breathing capacity. A definitive diagnosis requires a chest x ray or CT scan. If a diagnostician cannot interpret the images immediately, results may not be available for hours. In addition, x-ray and CT systems are so large and require so much electrical power that emergency squads and battlefield medics cannot use them in the field.

The noninvasive pneumothorax detector has a graphical user interface that guides the user in collecting data and displays the diagnosis on a readout screen. The procedure takes only 15 seconds, and results are processed immediately. The device is so simple to use that patients at risk of developing pneumothorax from a congenital defect or following a surgical procedure can carry a detector and continuously monitor their condition.

Livermore's UWB technology is compact and insensitive to acoustic and electromagnetic background noise. On an emergency rescue mission or in a chaotic trauma situation such as a moving ambulance, technicians using a stethoscope cannot always hear a person's breathing sounds. Detecting pneumothorax is especially important if a patient is to be airlifted to a treatment facility because the drop in air pressure could exacerbate symptoms.

To test the effectiveness of the UWB technology in a noisy environment, the Livermore team placed the cardiovascular monitor on the flight jacket worn by a helicopter pilot during takeoff. Even with the background noise from the helicopter, the monitor gave an accurate (negative) test result.

Lung

Project team for the noninvasive pneumothorax detector (from left): Mark Vigars, Gregory Dallum, John Chang, Christine Paulson, Patrick Welsh, and Garth Pratt.

The portable detector measures 1 centimeter by 2 centimeters and weighs less than 0.45 kilogram. Because the UWB technology uses commercial components, the projected cost is $1,000 per unit. For comparison, x-ray equipment can cost more than $15,000, and CT scanners run up to $250,000.

One Breath at a Time

Now licensed by ElectroSonics Medical, Inc. (previously called BIOMEC, Inc.), the noninvasive pneumothorax detector underwent final commercial development and clinical trials in 2000. In 2001, the Livermore team collaborated with BIOMEC and the MetroHealth Medical Center in Cleveland, Ohio, to assess the detector's accuracy.

Experiments using a pig established the technical feasibility of the device. The goal in these tests was to detect a pneumothorax with a volume as small as 60 milliliters, or about 4 tablespoons. Experimental results were remarkable, showing that the UWB signal clearly detected a pneumothorax as small as 30 milliliters.

In 2003, the National Institutes of Health funded a project to investigate the detector's capabilities in humans. For this research, the team tested a prototype device on 53 patients who had been examined for pneumothorax and were waiting to receive results from a chest x ray or CT scan. All patients in the study pool gave informed consent to participate in the research. In these tests, a clinician placed the detector's UWB antenna at eight defined locations on the patient and took readings at each location.

The overall accuracy of the prototype was 91 percent, with four false positives and one false negative. Accuracy decreased to 85 percent in tests to determine on which side of a patient's chest the pneumothorax was located. Researchers attributed the errors in part to the UWB antenna used in the prototype device. The antenna's wide beam spread caused its signal to cross over from one side of the chest to the other. For example, a measurement taken on the left side received echoes from a pneumothorax on the right side. According to Chang, reducing the beam spread and optimizing antenna placement on the body will improve the results. The team is looking at different antenna designs to control the beam spread.

In High Demand

Rapid diagnosis and treatment of pneumothorax can save lives and reduce morbidity. The noninvasive pneumothorax detector is in high demand in medical air transports, ambulances, hospital emergency rooms, and intensive care units. Veterinarians are also interested in the device because x-ray procedures on animals are expensive and can be difficult to perform. The project team expects civilian and animal services to create a demand of about 20,000 units in the U.S. alone—an attractive market for the device.

"We're making progress in moving the technology from bench-top prototype to clinical validation," says Chang. "We hope the detector will be implemented by emergency response teams and health-care providers to improve the outcome for critically injured individuals."

—Kristen Light

Key Words: chest trauma, chest x ray, collapsed lung, noninvasive pneumothorax detector, R&D 100 Award, ultrawideband (UWB) technology.

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